

# Clock-Tunable, High Accuracy, Quad 2nd Order, Analog Filter Building Blocks

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## Introduction

The LTC1068 product family consists of four monolithic, clock-tunable filter building blocks. Each product contains four matched, low noise, high accuracy 2nd order switched capacitor filter sections. An external clock tunes the center frequency of each 2nd order filter section. The LTC1068 products differ only in their clock-to-center frequency ratio. The clock-to-center frequency ratio is set to 200:1 (LTC1068-200), 100:1 (LTC1068), 50:1 (LTC1068-50) or 25:1 (LTC1068-25). External resistors can modify the clock-to-center frequency ratio. High precision, high performance, quad 2nd order, dual 4th order or single 8th order filters can be designed with an LTC1068 family product. Designing filters with an LTC1068 product is fully supported by the FilterCAD™ 2.0 design soft-

ware for Windows®. The internal sampling rate of all the LTC1068 devices is twice the clock frequency. This allows the frequency of input signals to approach twice the clock frequency before aliasing occurs. Maximum clock frequency for LTC1068-200, LTC1068 and LTC1068-25 is 6MHz with  $\pm 5V$  supplies; that for the LTC1068-50 is 2MHz with a single 5V supply. For low power filter applications, the LTC1068-50 power supply current is 4.5mA with a single 5V supply and 2.5mA with a single 3V supply. The LTC1068 products are available in a 28-pin SSOP surface mount package. The LTC1068 (the 100:1 part) is also available in a 24-pin DIP package. The following four circuits are typical examples of application-specific filters that the LTC1068 products can realize.

## LTC1068-200 Ultralow Frequency Linear-Phase Lowpass Filter

Figure 1 shows an LTC1068-200 linear-phase 1Hz lowpass filter schematic and Figure 2 shows its gain and group delay responses. The clock frequency of this filter is 400 times the  $-3dB$  frequency ( $f_{-3dB}$  or  $f_{CUTOFF}$ ). The large clock-to- $f_{CUTOFF}$  frequency ratio of this filter is useful in ultralow frequency filter applications when minimizing aliasing errors could be an important consideration. For example, the 1Hz lowpass filter shown in Figure 1 requires a 400Hz clock frequency. For this filter, the input frequencies that can generate aliasing errors are in a band from 795Hz to 805Hz ( $2 \times f_{CLK} \pm 5 \times f_{-3dB}$ ). For most very low frequency signal-processing applications, the signal spectrum is less than 100Hz. Therefore, Figure 1's filter will process very low frequency signals without significant aliasing errors, since its clock frequency is 400Hz and the aliasing inputs are in a small band around 800Hz.

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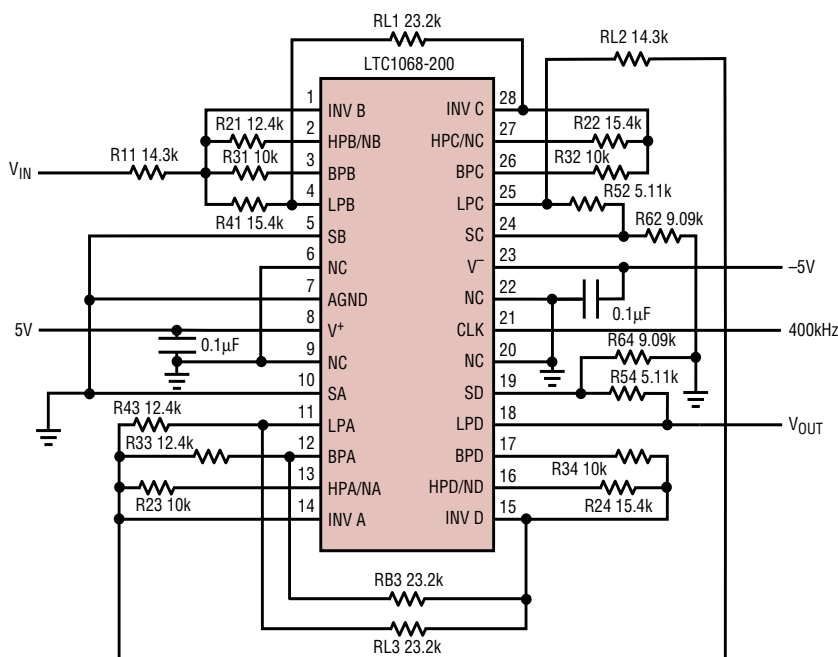


Figure 1. Linear-phase lowpass filter:  $f_{-3dB} = 1Hz = f_{CLK}/400$

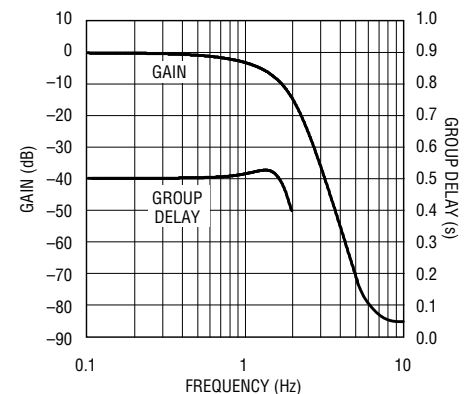


Figure 2. Gain and group delay response of Figure 1's circuit.

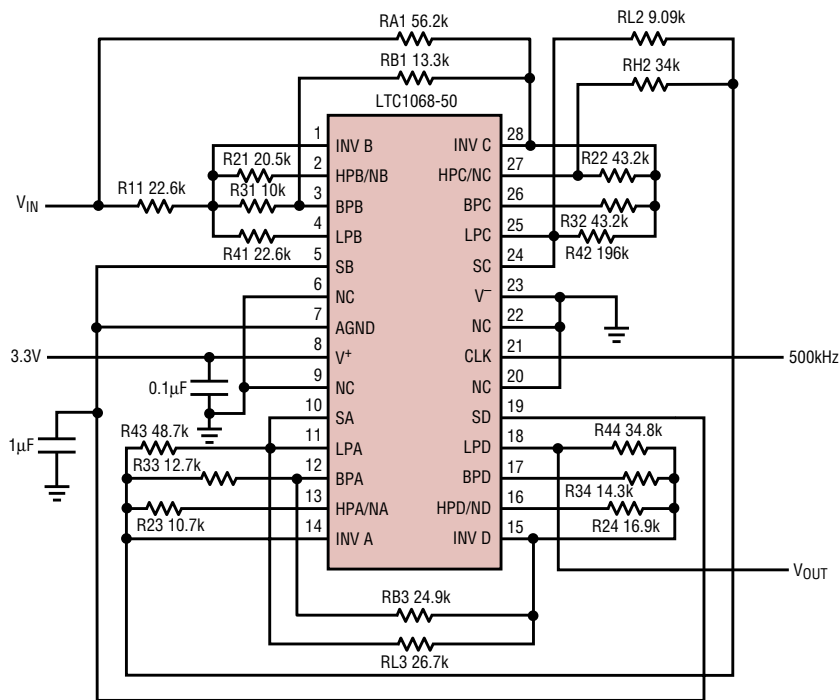


Figure 3. Low power, single 3.3V supply, 10kHz, 8th order, linear-phase lowpass filter

## LTC1068-50 Single 3.3V Low Power Linear-Phase Lowpass Filter

Figure 3 is a schematic of an LTC1068-50-based, single 3.3V, low power, lowpass filter with linear phase. The clock-to- $f_{\text{CUTOFF}}$  ratio is 50 to 1 ( $f_{\text{CUTOFF}}$  is the -3dB frequency). Figure 4 shows the gain and group delay response.

The flat group delay response in the filter's passband implies a linear phase. A linear-phase filter has a transient response with very small overshoot that settles very rapidly. A linear-phase lowpass filter is useful for processing communication signals with minimum intersymbol interference in digital communications transmitters or receivers. The

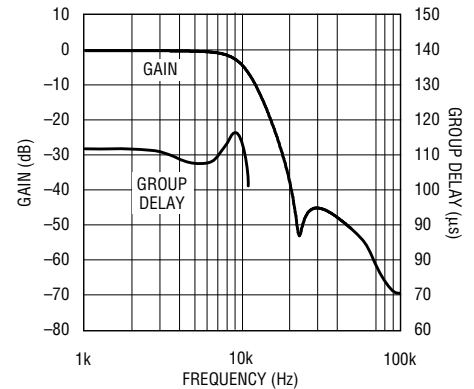


Figure 4. Gain and group delay response of Figure 3's filter

maximum clock frequency for this filter is 1MHz with a single 3.3V supply and 2MHz with a single 5V supply. Typical power supply current is 3mA with a single 3.3V supply and 4.5mA with a single 5V supply.

## LTC1068-25 Selective Bandpass Filter is Clock Tunable to 80kHz

Figure 5 shows a 70kHz bandpass filter based on the LTC1068-25 operating with dual 5V power supplies. The clock-to-center frequency ratio is 25 to 1. Figure 6 shows the gain response of Figure 5's bandpass filter. The passband of this filter extends from  $0.95 \times f_{\text{CENTER}}$  to  $1.05 \times f_{\text{CENTER}}$ . The stopband attenuation is greater than 40dB at  $0.8 \times f_{\text{CENTER}}$  and  $1.15 \times f_{\text{CENTER}}$ . The center frequency can be clock tuned to 80kHz with dual 5V supplies and to 40kHz with a single 5V supply. With FilterCAD, the LTC1068-25 can be used to realize bandpass filters less selective than that shown in Figure 6, which can be clock tuned up to 160kHz with dual 5V supplies.

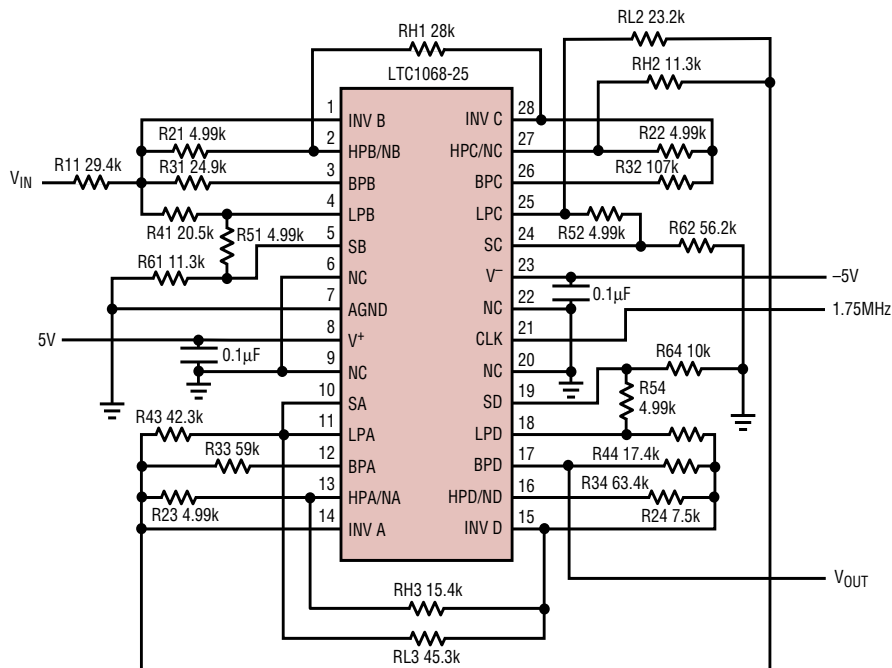


Figure 5. 70kHz, 8th order, bandpass filter

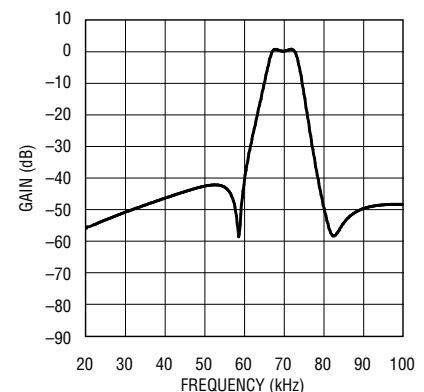
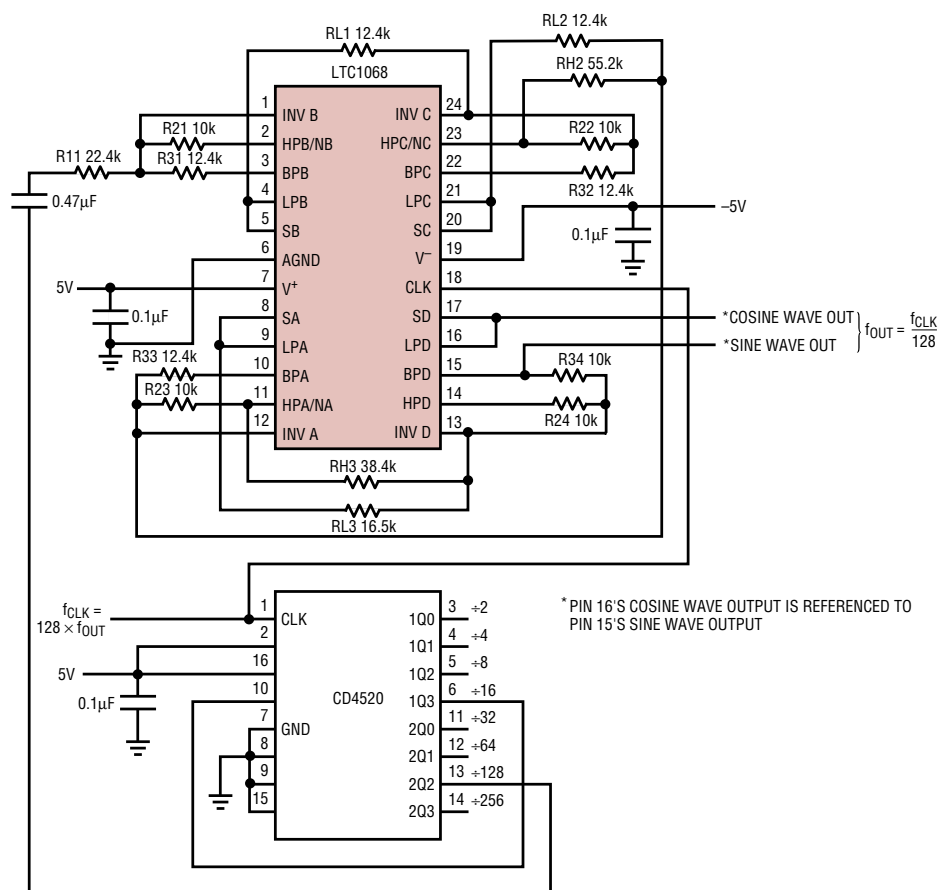


Figure 6. Gain response of Figure 5's filter



**Figure 7. Square-wave-to-quadrature oscillator converter**

## LTC1068 Square-Wave-to-Quadrature Oscillator Filter

Figure 7 shows the schematic of a LTC1068 based filter that is specifically designed to produce a low harmonic distortion sine and cosine oscillator from a CMOS-level square wave input. The reference sine wave output of Figure 7's circuit is on pin 15 (BPD on the 24-pin LTC1068 package) and the cosine output is on pin 16 (LPD on the 24-pin LTC1068 package). The output frequency of this quadrature oscillator is the filter's clock frequency divided by 128. The output of a CMOS CD4520 divide-by-128 counter is coupled with a 0.47µF capacitor to the input to the LTC1068 filter operating with dual 5V power supplies. The filter's clock frequency is the input to the CD4520 counter.

The LTC1068 filter is designed to pass the fundamental frequency component of a square wave and attenuate any harmonic components higher than the fundamental. An ideal square wave (50% duty cycle) will have only odd harmonics (3rd, 5th, 7th and so on), whereas a typical practical square wave has a duty cycle less or more than 50% and will also have even harmonics (2nd, 4th, 6th and so on). The filter of Figure 7 has a stopband notch at the 2nd and 3rd harmonics for a square wave input with a frequency equal to the filter's clock frequency divided by 128. The filter's sine wave output (pin 15) is 1V<sub>RMS</sub> for a ±2.5V square wave input and has less than 0.025% THD (total harmonic distortion) for input frequencies up to 16kHz and less than 0.1% THD

for frequencies up to 20kHz. The cosine output (on pin 16, referenced to pin 15's sine wave output) is 1.25V<sub>RMS</sub> for a ±2.5V square wave input and has less than 0.07% THD for frequencies up to 20kHz.

The 20kHz frequency limit is due to the CD4520; with a 74HC type divide-by-128 counter, sine and cosine waves up to 40kHz can be generated with the LTC1068-based filter of Figure 7.

## The LTC1068 Product Family: Versatile Filter Building Blocks, 1Hz to 200kHz

The previous four filter examples are typical of the great variety of filters that can be designed with the LTC1068 product family. As a general selection guide, the following is recommended: for low noise and low frequency filters less than 20kHz, use the LTC1068-200; for low noise and low frequency filters less than 40kHz, use the LTC1068; for low power filters up to 20kHz operating with single 3V to 5V supplies, the LTC1068-50 should be the choice; and for filters in the frequency range 40kHz to 200kHz, use the LTC1068-25. The FilterCAD design software will recommend the appropriate LTC1068 device for most filter applications. For some application-specific filter designs, the choice of the proper LTC1068 device may not be obvious and the assistance of a Linear Technology applications engineer will be helpful.

## LTC1068-Based Semicustom Filters

For application-specific filter requirements of single 8th order or dual 4th order filters, a customized version of an LTC1068-family product can be obtained in a 16-pin SO package with internal thin-film resistors. Clock-to-center frequency ratios higher or lower than 200:1, 100:1, 50:1 or 25:1 can also be obtained. Please contact LTC Marketing for details.

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